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Superfund Innovative Technology Evaluation Program Evaluation of Soil Amendment Technologies at the Crooksville/Roseville Pottery Area of Concern Rocky Mountain Remediation Services Envirobond™ Process

Innovative Technology Evaluation Report

National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Notice

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Foreword

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The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threatens human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

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E. Timothy Oppelt, Director
National Risk Management Research Laboratory

Abstract

Rocky Mountain Remediation Services, L.L.C. (RMRS), of Golden, Colorado, has developed Envirobond™ to treat soil contaminated with metals. RMRS claims that Envirobond™ forms metal complexes that immobilize toxic metals, thereby reducing the risk to human health and the environment.

The Superfund Innovative Technology Evaluation (SITE) Program evaluated an *in situ* application of the technology during a demonstration at two lead contamination sites in Roseville, Ohio, in September 1998. For the demonstration, Envirobond™ was applied to 10 experimental units at a trailer park and one experimental unit at an inactive pottery factory.

Primary objective 1 (P1) was to evaluate whether Envirobond™ can treat soil contaminated with lead to meet the Resource Conservation and Recovery Act (RCRA)/Hazardous and Solid Waste Amendments (HSWA) alternative universal treatment standards (UTS) for land disposal of soils contaminated with lead. The alternative UTS for soil contaminated with lead is determined from the results of the toxicity characteristic leaching procedure (TCLP). The alternative UTS is met if the concentration of lead in the TCLP extract is no higher than one of the following: (1) 7.5 milligrams per liter (mg/L), or (2) 10 percent of the lead concentration in the TCLP extract from the untreated soil. Contaminated soils with TCLP lead concentrations below the alternative UTS meet the RCRA land disposal restrictions (LDR), and thus are eligible for disposal in a land-based RCRA hazardous waste disposal unit. The alternative UTS is defined further under Title 40 of the Code of Federal Regulations (CFR), Chapter I, part 268.49 (40 CFR 268.49). To meet that objective, soil samples were collected before and after the application of Envirobond™. The untreated and treated soil samples were analyzed for TCLP lead concentrations to evaluate whether the technology met objective P1. Analysis of the data demonstrated Envirobond™ reduced the mean TCLP lead concentration at the inactive pottery factory from 382 mg/L to 1.4 mg/L, a reduction of more than 99 percent. Therefore, the treated soil meets the alternative UTS for soil at the inactive pottery factory. Data from the trailer park were not used to evaluate P1 because TCLP lead concentrations in all treated and untreated soil samples from this location were either at or slightly higher than the detection limit of 0.05 mg/L.

Primary objective 2 (P2) was to evaluate whether Envirobond™ could decrease the soil lead bioaccessibility by 25 percent or more, as defined by the Solubility/Bioaccessibility Research Consortium's (SBRC) Simplified In-Vitro Test Method for Determining Soil Lead and Arsenic Bioaccessibility (simplified in vitro method [SIVM]). However, EPA Lead Sites Workgroup (LSW) and Technical Review Workgroup for lead (TRW) at this time, do not endorse an in-vitro test for determining soil lead bioaccessibility (Interstate Technology and Regulatory Cooperation [ITRC] 1997). To meet objective P2, soil samples were collected before and after the application of Envirobond™. The soil samples were analyzed for soil lead bioaccessibility to evaluate whether the technology met objective P2. Analysis of the data demonstrates that Envirobond™ reduced the soil lead bioaccessibility by approximately 12.1 percent, which is less than the project goal of at least a 25 percent reduction in soil lead bioaccessibility. However, it was recognized early on that meeting this goal would be difficult because the SIVM test procedure used in the demonstration involves a highly acidic sample digestion process, which may be revised in the future, because it may be exceeding the acid concentrations that would be expected in a human stomach.

An economic analysis examined 12 cost categories for a scenario in which the Envirobond™ process was applied at full scale to treat 807 cubic yards lead contaminated soil at a 1-acre site within the CRPAC. The cost was estimated to be $41.16 per cubic yard of treated soil. However, the cost for using this technology is site-specific.

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Acronyms, Abbreviations, and Symbols

ACGIH TLV	American Conference of Governmental Industrial Hygiene Threshold Limit Value
ASTM	American Society for Testing and Materials
ARAR	Applicable or relevant and appropriate requirements
BS	Blank spike
$CaCO_3$	Calcium carbonate
CFR	*Code of Federal Regulations*
CEC	Cation exchange capacity
CRPAC	Crooksville/Roseville Pottery Area of Concern
cm^3	Cubic centimeter
DQO	Data quality objective
DUP	Duplicate
Eh	Oxidation reduction potential
EPA	U.S. Environmental Protection Agency
EP-TOX	Extraction procedure toxicity test
GI	U.S. Environmental Protection Agency Regional Geographic Initiative
HSWA	Hazardous and Solid Waste Act
ICP-AES	Inductively coupled plasma-atomic emission spectrometry
ITER	Innovative technology evaluation report
LCS	Laboratory control samples
LCSD	Laboratory control sample duplicates
MS	Matrix spike
MSD	Matrix spike duplicate
MEP	Multiple extraction procedure
Fg/dL	Micrograms per deciliter
Meq/g	Milliequivalents per gram
mg/kg	Milligram per kilogram
mg/L	Milligram per liter
mV	Millivolt
NAAQS	National Ambient Air Quality Standard
NCP	National Oil and Hazardous Substances Pollution Contingency Plan

Acronyms, Abbreviations, and Symbols (continued)

NIOSH REL	National Institute for Occupational Safety and Health recommended exposure limit
NPDES	National Pollutant Discharge Elimination System
NRMRL	National Risk Management Research Laboratory
OEPA	Ohio Environmental Protection Agency
ORD	Office of Research and Development
OSHA	Occupation Safety and Health Administration
OSHA PEL	Occupation Safety and Health Administration permissible exposure limit
OSWER	Office of Solid Waste and Emergency Response
PBET	Physiologically based extraction test
%R	Percent recovery
POTW	Publicly owned treatment works
PPE	Personal protective equipment
PRDL	Project-required detection limits
PRP	Potentially responsible party
QAPP	Quality assurance project plan
QA/QC	Quality assurance and quality control
RCRA	Resource Conservation and Recovery Act
RMRS	Rocky Mountain Remediation Services, L.L.C.
RPD	Relative percent difference
RPM	Remedial Project Manager
SARA	Superfund Amendments and Reauthorization Act
SBRC	Solubility/Bioavailability Research Consortium
SITE	Superfund Innovative Technology Evaluation
SIVM	Simplified in-vitro method
SPLP	Synthetic precipitation leaching procedure
SVOC	Semivolatile organic compound
TCLP	Toxicity Characteristic Leaching Procedure
TER	Technology Evaluation Report
µg/kg	Microgram per kilogram
µg/L	Microgram per liter
UTS	Universal treatment standard
VOC	Volatile organic compound
yd^3	cubic yard

Table of Conversion Factors			
	To Convert from	to	Multiply by
Length:	inch	centimeter	2.54
	foot	meter	0.305
	mile	kilometer	1.61
Area:	square foot	square meter	0.0929
	acre	square meter	4,047
Volume:	gallon	liter	3.78
	cubic foot	cubic meter	0.0283
	cubic foot	gallon	7.48
	cubic foot	cubic centimeter	28,317
	cubic yard	cubic meter	1.3
Mass:	pound	kilogram	0.454
	ton	kilogram	908
Temperature:	(° Fahrenheit - 32)	° Celsius	0.556

Acknowledgments

This report was prepared for the U.S. Environmental Protection Agency's Office of Research and Development, Superfund Innovative Technology Evaluation (SITE) Program by Tetra Tech EM Inc. under the direction and coordination of Mr. Edwin Barth, project manager for the SITE Program at the National Risk Management Research Laboratory, Cincinnati, Ohio.

Executive Summary

Rocky Mountain Remediation Services, L.L.C. (RMRS) has developed Envirobond™ to reduce the mobility of metals in soils. During September 1998, an *in situ* application of the technology was demonstrated under the U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) Program on soil contaminated with lead at two sites in Roseville, Ohio.

The purpose of this innovative technology evaluation report (ITER) is to present information that will assist Superfund decision makers in evaluating Envirobond™ for application at a particular hazardous waste site. This report provides an introduction to the SITE program and Envirobond™ and discusses the demonstration objectives and activities (Section 1); evaluates the technology's effectiveness (Section 2); analyzes key factors related to application of the technology (Section 3); analyzes the costs of using the technology to reduce the mobility of lead in soil, as well as the soil lead bioaccessibility (Section 4); summarizes the technology's current status (Section 5); and presents a list of references.

This executive summary briefly summarizes the information discussed in the ITER and evaluates the technology with respect to the nine criteria applied in Superfund feasibility studies.

Technology Description

RMRS claims that the Envirobond™ process can bind with metals in contaminated soils, sludges, mine tailings, process residuals, and other solid wastes. RMRS further claims that the Envirobond™ process converts each metal contaminant from its leachable form to a stable, nonhazardous metallic complex. The Envirobond™ process is a mixture of ligands that act as chelating agents. In the chelation reaction, coordinate bonds attach the metal ion to at least two ligand nonmetal ions to form a heterocyclic ring. By effectively binding the metals, RMRS claims that the Envirobond™ process reduces the waste stream's Toxicity Characteristic Leaching Procedure (TCLP) test results to less than the regulated levels, subsequently reducing the risks posed to human health and the environment.

Overview of the SITE Demonstration

The SITE demonstration of Envirobond™ was conducted in September 1998 at two sites in Roseville, Ohio: an inactive pottery factory and a trailer park. Both sites are located in the Crooksville/Roseville Pottery Area of Concern (CRPAC). Historically, the CRPAC was a major pottery manufacturing area. Lead was used in the glazing process of the pottery finishing process; as a result, has contaminated the upper portion of the soil layer. Soil samples collected by the Ohio Environmental Protection Agency (OEPA) in 1997 indicated that elevated levels of lead were present in the CRPAC. Waste disposal practices and residue from the operation of the kiln at the inactive pottery factory may have contributed to contamination of the soil adjacent to the factory. Waste from several pottery factories in the CRPAC was used as fill material in the vicinity of the trailer park. The fill material may be the source of the lead contamination of the soil at the trailer park.

For the SITE demonstration, soil samples were collected before and after application of Envirobond™ to evaluate whether the technology could achieve the treatment goals of the demonstration project. The project had two primary objectives and four secondary objectives.

The primary objectives of the SITE demonstration were

- Primary Objective 1 (P1) - Evaluate whether Envirobond™ can treat soils contaminated with lead to meet the Resource Conservation and Recovery Act (RCRA)/Hazardous and Solid Waste Amendments (HSWA) alternative universal treatment standard (UTS) for land disposal of soils contaminated with lead that meet the definition of a hazardous waste. The alternative UTS for lead in such soil is determined from the results of the toxicity characteristic leaching procedure (TCLP). The alternative UTS for lead is met if the concentration of lead in the TCLP extract is no higher than one of the following: (1) 7.5 milligrams per liter (mg/L), or (2) 10 percent of the lead concentration in the TCLP extract from the untreated soil. The alternative UTS is defined further in Title 40 of the Code of Federal Regulations (CFR), Chapter I, part 268.49 (40 CFR 268.49).

- Primary Objective 2 (P2) - Evaluate whether Envirobond™ can decrease the soil lead bioaccessibility by 25 percent or more, as defined by the Solubility/Bioaccessibility Research Consortium's (SBRC) In-Vitro Method for Determination of Lead and Arsenic Bioaccessibility (simplified in-vitro method [SIVM]) (Note: the EPA Lead Sites Workgroup (LSW) and Technical Review Workgroup for lead (TRW) at this time do not endorse an in vitro test for determining soil lead bioaccessibility [ITRC 1997]).

The secondary objectives of the demonstration were

- Secondary Objective 1 (S1) - Evaluate the long-term chemical stability of the treated soil.

- Secondary Objective 2 (S2) - Demonstrate that the application of Envirobond™ did not increase the public health risk of exposure to lead.

- Secondary Objective 3 (S3) - Document baseline geophysical and chemical conditions in the soil before the application of Envirobond™.

- Secondary Objective 4 (S4) - Document the operating and design parameters of Envirobond™.

SITE Demonstration Results

Summarized below are the significant results of the SITE demonstration:

- Envirobond™ reduced the mean TCLP lead concentration from 382 mg/L to 1.4 mg/L at the inactive pottery factory, a reduction of more than 99 percent. Therefore, the treated soil meets the alternative UTS for soils contaminated with lead, as specified at CFR 268.49. Data from the trailer park were not used to evaluate P1 because TCLP lead concentrations in all treated and untreated soil samples from this location were either at or slightly higher than the detection limit of 0.05 mg/L.

- Analysis of the data generated by application of the SIVM demonstrated that Envirobond™ reduced the soil lead bioaccessibility by approximately 12.1 percent. However, it was recognized early on that meeting this goal would be difficult because the SIVM test procedure used in the demonstration involves a highly acidic sample digestion process, which may be revised in the future, because it may be exceeding the acid concentrations that would be expected in a human stomach.

- Soil treated with Envirobond™ appears to exhibit long-term chemical stability, as indicated by the results of most of the 11 analytical procedures that were conducted to predict the long-term chemical stability of the treated soil. However, the results of some of the analytical procedures suggest that Envirobond™ does not appear to exhibit long-term chemical stability. In summary:

  — Long-term soil chemical stability was indicated for soils treated by Envirobond™ at both test locations, as indicated by the analytical results of the multiple extraction procedure (MEP), the procedure for lead speciation by sequential extraction, the test for cation exchange capacity (CEC), and leachable lead by the simulated precipitation leaching procedure (SPLP). The CEC results are considered to be qualitative, because this test was conducted on only a single sample from each location.

  — Long-term chemical stability was indicated at one site, but not at the other, by the analytical results of procedures for evaluating acid neutralization capacity. The acid neutralization results are considered to be qualitative, because this test was conducted on only a single sample from each location.

  — The analytical results from the lead speciation test by scanning electron microscopy (conducted only on soils from the trailer park) were mixed, in that the silica phosphate phase (low solubility) of lead was increased and some soluble phases of lead were reduced, while other low-solubility phases of lead were also reduced.

  — At both locations, long-term chemical stability was not indicated for soils treated by Envirobond™ by the results of the pH analyses, Eh analyses, separate analyses for total lead by nitric and hydrofluoric acids; total phosphates; and SPLP phosphates (It should be noted that the tests involving two types of total lead analysis were extremely aggressive tests, thus meeting the acceptance criteria established for these tests was not as important as meeting the acceptance criteria of other tests involving long-term chemical stability).

- As the analytical results for the air samples demonstrated, the dust generated during site preparation activities prior to the application of Envirobond™ may exceed the National Ambient Air Quality Program Standard for lead of 1.5 micrograms per cubic meter of air. Therefore, if it is determined that it is necessary to remove the soil or use other techniques that might generate

dust, it is recommended that air monitoring (with real-time devices correlated to actual lead concentrations in the air) be employed; and, if necessary, dust suppression measures also should be employed.

- Based on visual observations during the demonstration, the application of Envirobond™ does not appear to create significant quantities of dust.

- On the basis of information obtained from the SITE demonstration, RMRS, and other sources, an economic analysis examined 12 cost categories for a scenario in which Envirobond™ was applied at full scale to treat 807 cubic yards (yd^3) of soil contaminated with lead at a 1-acre site at CRPAC. The cost estimate assumed that the concentrations of lead in the soil were the same as those encountered during the Roseville demonstration. On the basis of those assumptions, the cost was estimated to be $41.16 per yd^3 of treated soil, which is a site-specific estimate.

Superfund Feasibility Study Evaluation Criteria for the Envirobond™ Process

Table ES-1 presents an evaluation of Envirobond™ with respect to the nine evaluation criteria used for Superfund feasibility studies that consider remedial alternatives for superfund Sites.

Table ES-1. Evaluation of Envirobond™ by Application of the Nine Criteria for Superfund Feasibility Studies

Criterion		Discussion
1.	Overall Protection of Human Health and the Environment	The technology is expected to significantly lower the leachability of lead from soils as indicated by the TCLP results, thereby reducing the migration of lead to groundwater and the potential for exposure of all receptors to lead; however, the technology did not significantly reduce soil lead bioaccessibility, as determined by the SIVM.
2.	Compliance with Applicable or Relevant and Appropriate Requirements (ARAR)	During the SITE demonstration, Envirobond™ reduced the mean TCLP lead concentration from 382 mg/L to 1.4 mg/L, a reduction of more than 99 percent. Further, the treated TCLP lead concentrations were less than the alternative UTS for lead in soil. Therefore, the treated soil met the land disposal restrictions (LDR) for lead-contaminated soil, as specified in 40 CFR 268.49. However, the technology's ability to comply with existing federal, state, or local ARARs should be determined on a site-specific basis.
3.	Long-term Effectiveness and Permanence	The analytical results of procedures for the multiple extraction procedure (MEP), the procedure for lead speciation by sequential extraction, the test for cation exchange capacity (CEC), and leachable lead by the simulated precipitation leaching procedure (SPLP) suggest long-term chemical stability of the treated soil. The analytical results of a number of other procedures do not suggest long-term chemical stability of the treated soil. Those procedures included pH analyses, Eh analyses, separate analyses for total lead by nitric and hydrofluoric acids; total phosphates; and SPLP phosphates. The results related to long-term effectiveness from the test for lead speciation by scanning electron microscopy and acid neutralization were inconclusive.
4.	Short-term Effectiveness	Short-term effectiveness is high; measures to control dusts and surface runoff controls may be needed at some sites.
5.	Reduction of Toxicity, Mobility, or Volume Through Treatment	The mean TCLP lead concentration was reduced from 382 mg/L to 1.4 mg/L, reducing the mobility of the lead in the soil.
6.	Implementability	The technology is relatively easy to apply. Large areas can be treated using common farm equipment, and small areas can be treated using readily available home gardening tools (sod cutter, tiller, fertilizer sprayer).
7.	Cost	For full-scale application of the technology at a 1-acre site contaminated with lead in the top 6 inches of soil, estimated costs are $33,220, which is $41.16 per cubic yard.
8.	Community Acceptance	Community acceptance of Envirobond™ likely will be a site-specific issue.
9.	State Acceptance	State acceptance of Envirobond™ likely will be a site-specific issue.